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ORIGINAL PAPER

Measuring the Sympathetic Skin Response on Body and Using as Diagnosis-Purposed for Lung Cancer Patients by Artificial Neural Networks

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Abstract In this study, the points of Sympathetic skin response that can be measured from different zones on body of healthy and patient subjects are determined. The Sympathetic skin responses on these points are obtained using a measurement device that is called Grass Model 7 Polygraph 1. The database is formed in Cerrahpaşa University, Faculty of Medicine and data is taken from healthy and patient subjects who are volunteer. Some parameters of the subjects which are more effective on SSR such as height, weight, age must be chosen between the specific limits to obtain results more clearly. The symmetric points on human body are chosen for the measurement. After that, the Sympathetic skin response values which are measured from a human body are simulated and tested by using artificial neural network toolbox on Matlab software. The structure of the chosen neural network is a multilayer feedforward neural network. According to simulation results, the application method as diagnosis-purposed of the lung cancer patients is explained by using the differences related to these values on the skin.

Keywords Skin · Sympathetic skin response · Artificial neural networks · Lung cancer

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Introduction

Sympathetic skin response (SSR), defined as the momentary change of the electrical potential of the skin, may be spontaneous or reflexively evoked by a variety of internal or by externally applied arousal stimuli. Although the suprasegmental structures influencing the SSR in humans are not well known, SSR has been proposed as a non-invasive approach to investigate the function of the sympathetic system. SSR is easy to apply but current procedures are not sufficiently reliable for diagnostic purposes, and show imperfect correlations both with clinical features and other measurements of autonomic, in particular, sudomotor dysfunction.

Skin itself is the heaviest organ of body. It makes up 16% of total body weight, and it has 1.2–2.3 m^2 surface of an adult body. Skin is composed of these three fractions; epiderm, dermis and subcutaneous. The border of dermis and epiderm is disordered, and dermis extensions called papilla are interlocked with epiderm papules called epidermal overhangs in an interpenetrative order. If examining three- dimensionally, these interpenetrations have a consistency like plug and plug contact (thin skin) or swellings and grooves (thick skin). Hair, nail, sweat glands and sebaceous glands derive from epiderm. A spongy connective tissue called hypodermic tissue lies down under dermis. Hypoderm is in charge of linking skin to bottom tissues; however, it is no regarded as a part of skin [1].

Related researches display that there are changes in reaction of SSR which are on diseased land that affected especially autonomous nerves system (ANS) [2]. According to results of these analyses, it is agreed that quantitative values which are gathered can be clarified by using one of the soft- computing techniques [3].

Table 1 Average values and limits of the subjects' ages and defined physical features

Parameters	Average values	Limits
Age	33	16–61
Height	171.6	155–185
Weight	65.08	49–84

The most effective part of skin is sweat glands on SSR. Sweat glands are classified into apocrine and ecrine type, even if the mechanisms of sweat secretion are probably the same [4]. Eccrin sweat gland which is important for the electrodermal activity is innervated by the sympathetic cholinergic fibers and the activation of these fibers increases the sweat secretion. As a result of this activation, skin resistance changes [5].

SSR originates by activation of the reflex arch with different kinds of stimuli. The potential of rapid habituation after repeated stimuli is formed by biphasic or triphasic slow wave activity with relatively stable latency and variable amplitude. In healthy subjects younger than 60 years of age the response is always present in all extremities. SSR is most frequently used in diagnosing the functional impairment of non-myelinated postganglionic sudomotor sympathetic fibers in peripheral neuropathies [6].

The aim of this study is to obtain significant results by benefitting from reaction of SSR measurements for lung cancer patients and using artificial neural networks, and also to reveal new methods as the purpose of diagnosis for future researches.

Sympathetic skin response and its importance

SSR was first noted by Tarchanoff who assigned the potential change to modification in the humoral activity of sweat glands independent of the vascular reaction [7]. Shahani et al. first described applications of SSR in clinical neurophysiology [8]. SSR is one of the most frequently used measurements in psychophysiological studies.

There are some kinds of skin components to forward electric current such as hypodermic liquid areas and tissues, metals in contents of human body. This transmission is faithfully ionic which means electric current goes ahead on skin depending on concentration difference. Researches show that there are positive and negative ions inside and outside the cell, and there are some potential discrepancies between inside and outside the cell by means of these ions [9].

SSR can vary depending on psychological and physiological factors in human body. Nonetheless, the resistance values can be different almost at every point of human body by considering differences in components of skin. At the same time, the type of current to be used in measurement has impact on this value. For instance, arm's dry skin resistance of a healthy person was measured 4 MΩ at DC under normal circumstances. By the same application, it was measured at AC in low frequency (20–25 Hz), and it was noted as 300 KΩ [10].

If nerves are damaged in any parts of the body, a dramatic rise is noted in skin resistances that are close to that part. Therefore, sympathetic skin response is utilized as an advanced diagnosis for diseases in medical science [11].

Material and methods

The measurements are taken from 13 healthy (medical personnel) and 9 patient subjects who are also under cure at Cerrahpaşa University, Faculty of Medicine, Physiotherapy and Rehabilitation Center. SSR measurements were carried out at six different points of subject's bodies. While measuring, psychological mood of the subjects are tried to be in good condition as possible. Patients are sitting or reclining in a comfortable, relaxed position and laboratory situation must be quiet and stressless during the recording.

Before the SSR measurements are obtained, some parameters of the subjects which are more effective on SSR (height, weight, age) must be chosen between the specific limits to obtain more clearly results [12]. In Table 1, the limits and the average values of the subjects are shown.

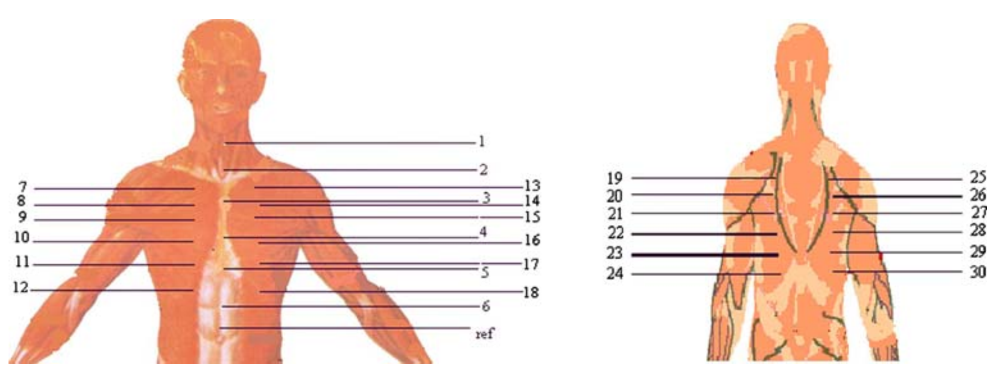


Fig. 1 Points of measurement taken

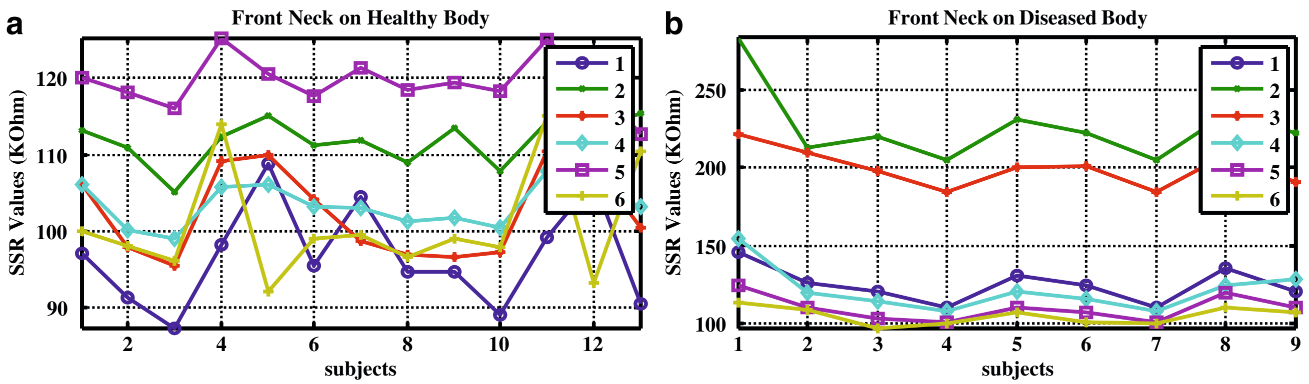


Fig. 2 Measurement values taken between neck and reference point for: (a) healthy subjects (b) diseased subjects

In the application, Grass Model 7 Polygraph 1 measurement device is used. This device has an accurate, chopper-modulated and demodulated, high gain, low noise, low frequency, highly stable DC preamplifier. It permits recording of electroencephalogram (EEG), electrocardiogram (EKG) and respiration as an AC amplifier. Its frequency response is up to 47 Hz.

SSR is measured by using 50 μA DC current between 0.8 – 0.9 cm long electrodes that are set up on the measured and saved. One of the electrodes is positioned somewhere on the central part which is accepted as reference. The other electrode is used as active electrode. A special conductive gel is utilized so as to make contacts between electrodes and skin. Potential difference between apparatus and electrodes is saved as mV. 1 mV potential difference equals 10 KΩ resistance value in the measuring apparatus. Therefore, measurement values are evaluated in mV and defined in KΩ after multiplying by 10.

SSR of the participants on different points are measured by means of the method described above, and they are saved to use.

The points to be used as input data are chosen depending on whether the measurement region is related to lung cancer. For this reason, major changes are noted in terms of response of skin in areas of chests and backs, also measurement points between necks and reference of lung cancered patients; especially measurement values of these regions are recorded to analyze the data.

The SSR measurements obtained from the points which are illustrated in Fig. 1 are shown on graphics for Measurement values taken between neck and reference point in Fig. 2, for measurement values taken from the front-right part of body in Fig. 3, Measurement values taken from front-left part of body in Fig. 4, Measurement values taken from left-back part of body in Fig. 5, and Measurement values taken from right-back part of body in Fig. 6. Measurement results of healthy and diseased subjects are compared on graphics.

In the graphics, the horizontal axis shows the sequence of healthy and diseased subjects and the vertical axis shows the value of the SSR. The series represents the sequence of the measurement points which are given in Fig. 1.

Analysis of input data with artificial neural network

Having measured input data with the help of Grass Model 7 Polygraph 1, SSR is investigated if it would help diagnosis of lung cancer by using Matlab software.

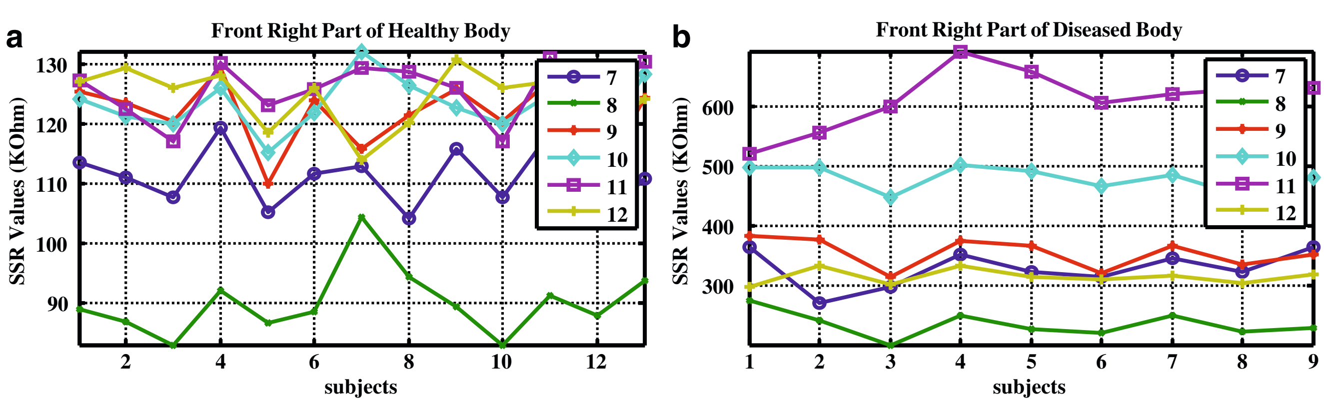


Fig. 3 Measurement values taken from the front-right part of body for: (a) healthy subjects (b) diseased subjects

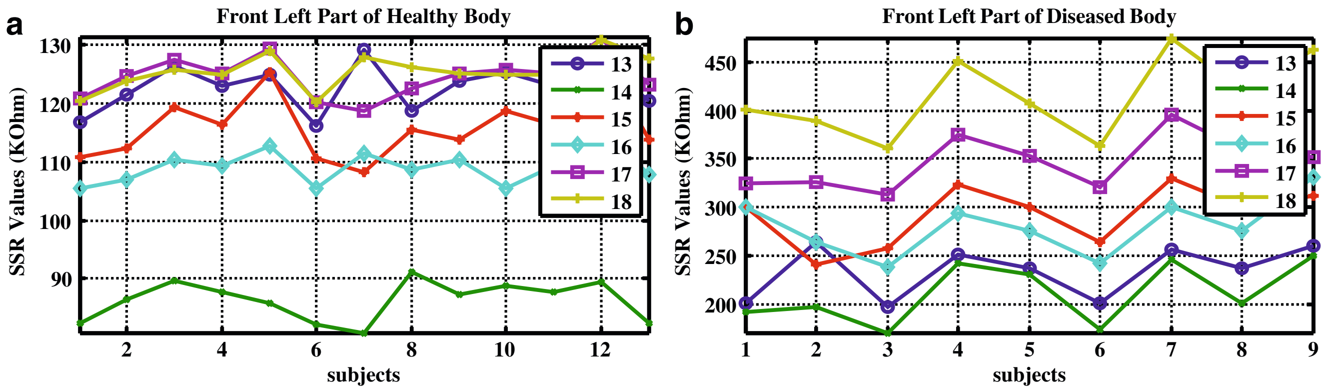


Fig. 4 Measurement values taken from front-left part of body for: (a) healthy subjects (b) diseased subjects

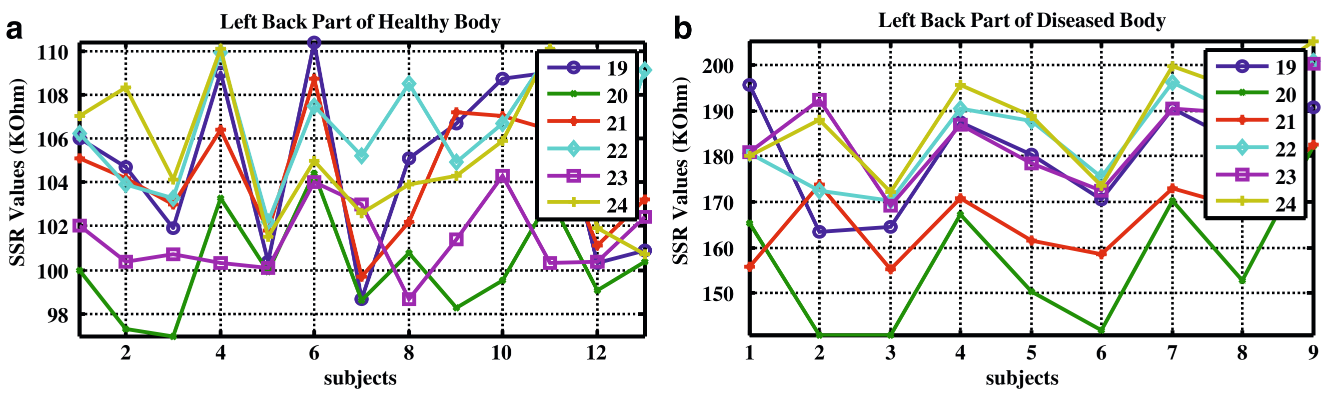


Fig. 5 Measurement values taken from left-back part of body for: (a) healthy subjects (b) diseased subjects

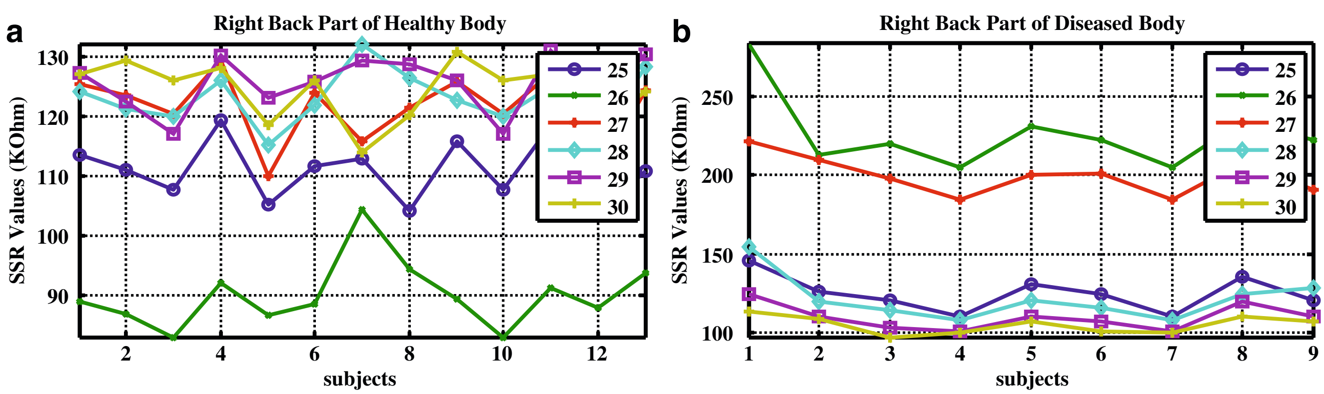
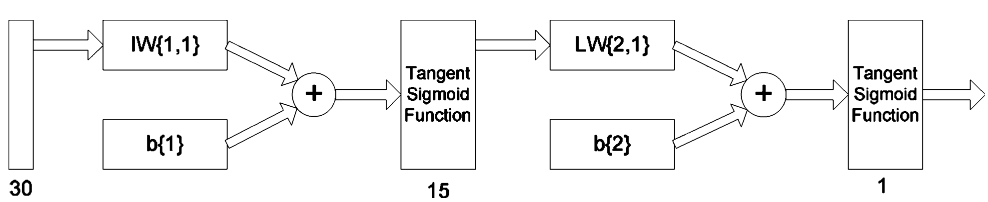


Fig. 6 Measurement values taken from right-back part of body for: (a) healthy subjects (b) diseased subjects

Fig. 7 Architecture of YSA model



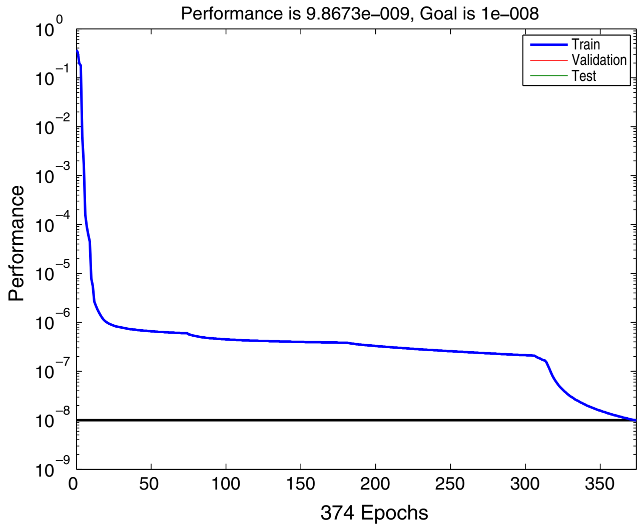


Fig. 8 Training with Trainlm

First of all, measurement results of premier eight of healthy subjects and premier six of diseased subjects are used for the purpose of training. The rest of the input data is selected as test set.

Selecting Network Type Multilayer Feedforward Neural Network (MFFNN) is selected for study. The multilayer feedforward neural network is the most commonly used algorithm in all the possible structures of neural networks. The standard algorithm for any supervised-learning pattern recognition processes are the most used classification method Multilayer perceptrons using a backpropagation algorithm. Backpropagation is a common method of training artificial neural networks how to perform a given task. It was first described by Paul Werbos in 1974 [13]. Backpropagation Algorithm is the most commonly used algorithm in artificial neural networks. The network put the input pattern through the neurons in confidential layers which are in the output neurons to deduce the consequences. Then the expected result and gathered result are compared to find out errors in output layer. Later, the derive of output errors are put through the output layer retrospectively. Finding out error values, neurons balance their own weights to decrease their errors. Equations for weight change are balanced to minimize the performance function on the network [14]. There are many variations of the backpropagation algorithm. The simplest implementation of backpropagation learning updates the network weights and biases in the direction in which the performance function decreases most rapidly - the opposite of the gradient. An iteration of this algorithm can be written

$$x_{k+1} = x_k - a_k g_k, \tag{4.1}$$

where x_k is a vector of current weights and biases, g_k is the current gradient, and a_k is the learning rate [15].

Identifying Training Function "Levenberg-Marquardt Learning Algorithm" was selected considering its process speed well in terms of training function. Levenberg-Marquardt Learning Algorithm uses standard quantitative optimization techniques. Levenberg-Marquardt Algorithm (LMA) was first discovered by Kenneth Levenberg in 1944 [16]. It is a technique that generally finds out "numeric solution" by minimizing function generally on a parameter space that is not linear. Minimizing problems are such kinds of programmes that are not linear and fabricate curves with especially the smallest squares. Like other types of optimization problems, there is a movement like iterations in Levenberg-Marquardt. For instance; random initial values were given to a parameters vector to minimize the function

$$S(a) = \sum_{i=1}^{n} [y_i - f(x_i|a)]^2 \quad a_i = (1, 1, 1, \ldots, 1) \quad [\mathrm{i} = 1, 2, \ldots, \mathrm{n}] \tag{4.2}$$

In each stage, a parameter vector is reestimated as $a+q$. Linear value of $f_i(a_+q)$ is calculated approximately to presume q quantum leap.

$$f_i(a+q) \approx f(a) + Jq \tag{4.3}$$

In this equation, J is the jacobien in a of the function. *S(a)* is 0 in q point where *S(a)* function is minimum. This equation arises below after the equation is combined with 4.3, taken derives of it and equals 0;

$$(J^T J)q = -J^T f \tag{4.4}$$

The key point of LMA method is the addition of amortization factor to the equation. After adding amortization factor, the final version of the equation is;

$$(J^T J + \lambda I)q = -J^T f \tag{4.5}$$

Here I is unit matrix. λ is not a negative number that changes *S(a)* in each iteration, and it was defined by user intuitively. Change of λ parameter in each parameter is

Table 2 Target results and estimated results after simulation

Target results	1	1	1	1	1	0	0	0
Estimated results	0.9999	0.9999	0.9999	0.9999	0.9999	0.00011184	0.0025022	0.00079598

generally obtained with the help of an additional parameter like *v*. Like λ, *v* is identified intuitively. If *S(a)* whose minimization is wanted provides the desired decline at the purpose function, λ is divided into *v*. If unexpected result obtained in the related iteration, and a high *S(a)* value is seen, λ is multiplied with *v* [16].

Learning algorithms arise as an alternative algorithm to the previous ones; it aims at developing great parts of the previous ones and decreasing bad parts. Levenberg – Marquardt Algorithm is composed of the best parts of Newton and Gradient decline Algorithms and erases limitations of it [14].

To get more definite results, the number of neurons in hidden layer was changed between ten and forty, and results were evaluated. As a result of this, the number of neurons that gave the best result was noted fifteen.

The structure of Artificial Neural Network is seen in Fig. 7. There are thirty inputs taken from diseased affected parts in the input part of the network. As stated above, fifteen neurons were exploited in the hidden layer. A single output is seen as zero for diseased subjects' input and one for healthy subjects' input at the exit part.

The goal was 10^{-8} for a mean squared error. Levenberg – Marquardt Algorithms reached the goal at approximately 274 epochs as seen in Fig. 8.

Artificial Neural Network which was trained using training data has been tested with test data. Estimated results and target results are approximately same. Thus it is seen that Artificial Neural Network is 100% successful. The results are shown in Table 2

Results and recommendations

In this study, sympathetic skin response measurements were carried out in points related to lung cancer with the help of Grass Model 7 Polygraph 1 measuring device, and it was noted that input values taken from lung cancered patients are more rather higher than that of healthy subjects. In other words, results were gathered to suppose that response of sympathetic skin can be used as diagnosis of lung cancer if considering the values.

Furthermore, response of sympathetic skin result values taken from related parts to the disease of healthy and diseased subjects were analyzed in Matlab. When estimated and target results are compared, 100 % accuracy is obtained. This situation increases the possibility of using SSR as a diagnosis technique.

In future researches related to this study, if the number of input taken from body increases, there will be no deviation; nonetheless, also algorithm can be obtained considering the parameter after accepting subject's psychological situations as a kind of parameter.

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